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THE RAILWAY PROBLEM

AND THE

RAILWAYS OF THE FUTURE.

Re-printed from the "Times."

19th, 20th, 21st October, 1869, and 18th February and 1st March, 1870.

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AND HARP ALLEY, E.C.

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THE RAILWAY PROBLEM.

19th October, 1869.

I.

Two prodigious statements have been made this year in regard to railways which are well calculated to strike the popular imagination, and to convey in a compendious form all that we know of railway mismanagement. The first is a statement made by Mr. Laing as to certain branch lines constructed for the Brighton Railway, that the shareholders who subscribed the capital of £4,000,000 towards their construction might as well, for any benefit which can accrue to themselves, have taken bank notes to this amount and used them to light their pipes with. That is certainly a vivid description of the waste of money laid out in branch lines which can bring no return. It shows that there must be something radically wrong about them. The fact is that from the first we have spent too much money on railways; but this was excusable for a long time, since we had much to learn and had to pay dearly for our experience. But the waste which was pardonable in our main lines became profligate when it was permitted in branch ones. There has been a wicked want of consideration, not indeed with respect to the localities into which these branches run, but as regards the cost which should be incurred in their construc-

tion. We need not stay to inquire into the motives which have led to so much waste; but we may point out in a few words how utterly indefensible has been the outlay. Let us imagine a trunk line of railway with eight or ten branches. The trunk line having cost, say £20,000 a mile, has to carry over it not only its own traffic but that of the ten branches besides, Strange to say, the branch lines have in many cases cost more than the parent line, although it is but fair to assume that not one-twentieth part of the traffic of the trunk could pass over the branch. How is it possible for these branches to pay? In the Isle of Wight some of the railways have cost £30,000 a mile of single line, where it is not too much to say that the traffic, which is chiefly for pleasure, and therefore of a light character, might easily have been carried on railways of much slighter structure, that would have cost, including the rolling stock, no more than £5,000 a mile. And now there is a cry for more and more railways and for more and more branches. Any one, indeed, who will take serious note of these demands all over the country must see that our railway system is not yet nearly completed. Innumerable roads have yet to be formed, and it is impossible that shareholders will subscribe to them if there is not to be some radical change in the conditions under which they are to be constructed and worked. It will not do to go on lighting pipes with millions of bank notes.

The other prodigious statement to which we have referred is one which Mr. Haughton, of the North-Western Railway, made in a letter to ourselves the other day, though he is not alone responsible for it. Mr. Fairlie, in his paper read before the Society of Arts last year, Mr. Haughton, in his paper read before the Society of Civil Engineers, and Mr. Haggard, in his pamphlet entitled *A Mile of Railway*, proved very clearly that there is an enormous disproportion between the net and tare of train loads. In Mr. Haggard's pamphlet it is stated, on figures furnished by Mr. Haughton, that every passenger carried by rail weighs a ton; in other words, that supposing a passenger and his luggage to weigh in reality two hundredweight, the rolling stock which has to be set in motion in order to convey him to his destination multiplies his weight tenfold, so that from every passenger a ton has to be hauled. Mr. Haughton then corrected his figures, and in a letter addressed

to ourselves, as well as in his paper read to the Society of Civil Engineers, showed that every passenger weighs two tons; and Mr. Fairlie asserts that the calculation has to be still further corrected, for the actual weight of a passenger as carried by rail is not less than two tons and a quarter. In this last statement of the case Mr. Fairlie is confirmed by another engineer, Mr. Samuel, who declares that for every ton of passengers the engine has to draw 33 tons of load, and who reckons the average real weight of a passenger at a hundredweight and a-half, not as Mr. Haughton, at two hundredweight. In the goods trains the disproportion between the paying and the non-paying weights is not so extravagant, though it is great enough in all conscience. According to Mr. Haughton's calculation no more than 30 per cent. of the load which is hauled by a goods train represents paying weight; the remaining 70 per cent. is dead weight. Such a statement as this would of itself be astounding were it not eclipsed by the statement as to passenger trains that only 5 per cent. of the load pays according to Mr. Haughton, and only three per cent. according to Messrs. Fairlie and Samuel, the remaining 95 or 97 per cent. being mere dead weight, without which it is said to be impossible to carry the poor little per-centage of paying load. Let us think for a moment what this means. An ordinary omnibus may be assumed to weigh a ton, and its two horses, with their harness, are over-estimated at another ton. It carries 28 passengers, who, having little or no luggage, may be estimated at two tons. The paying and the non-paying loads thus balance each other. There is 50 per cent. of the one and 50 of the other. This is what occurs on ordinary roads where traction is difficult. What should we expect on the rail, where traction is easy? Is it not monstrous that the average dead weight of our passenger trains should, by the lowest reckoning, be 95 per cent. of the entire weight?—that to compare the figures with those of the omnibus it is necessary for the carriage of two tons of passengers to set in motion, not as in the omnibus twice, but actually 20 times the weight of rolling stock and freight combined? Or, to return to the succinct statement of Mr. Haughton, that every passenger should weigh two tons, and of Mr. Fairlie, that he should weigh two tons and a quarter? Surely there is a gigantic mistake somewhere. Surely this enormous waste of power

cannot be necessary. Surely it must be a severe reproach to mechanical science, so long as a ton of passengers means, according to one calculation, 20 tons, or according to another, 33 tons of load to be carried, and that not on rough ordinary roads, but on rails.

It is impossible to acquiesce in such a state of things, and the first thought which must cross one who reads of it is that the engineer who describes it is instantly going to propose, good or bad, some remedy. What is our amazement on reading Mr. Haughton's paper to find that remedy there is none! His paper is written to show that it is impossible to reduce railway fares. To the popular demand for reduction of fares he points out, truly enough, what an enormous work the locomotive has to perform. Every passenger behind the locomotive weighs a couple of tons, and how can people expect railway companies to lower the fares on such a load? If we argue that the amount of dead weight is excessive and must diminish as science improves, we are told by Mr. Haughton that, on the contrary, dead weight has been of late years on the increase, and that "by no known processes can those enormous multiplications of original net weight be reduced consistently with affording that amount of personal security and comfort and accommodation now enjoyed." If we are to accept this as the last result of engineering science, there is certainly a bad look-out for the fares of passengers and for the dividends of shareholders. Mr. Haughton seems to regard it as the height of extravagance to look for benefit to either. Railways have certainly taught people to be extravagant. They have achieved such wonders that they have raised unbounded expectations. We hear of some worthy people, for example, able men, too, who at the last meeting of the British Association proposed that Government should take possession of all the railways in the kingdom, and should establish a uniform fare for all distances, say of a shilling for the first class, which would convey a passenger equally well from London to Greenwich and from London to Inverness. These are wild dreams; but surely not less wild is the dream of the satisfied engineer who tells us that the enormous waste of power expended on our railway trains is natural and inevitable, and that by no known process can we improve upon the present state of things. If Mr. Raphael Brandon, who imagines

that he can travel from London to Inverness for a shilling, be a dreamer of the first magnitude, surely he is not less a dreamer who is so wedded to the established order of things that he cannot conceive of any process by which the present prodigious waste of power on railways can be diminished without affecting the safety and the comfort of passengers. Mr. Haughton and others quote a little too freely, using as a kind of proverb the statement of *The Times* that we have here in England "the best served travelling community in the world." Does it follow that this community of travellers cannot be better served, that the not less important community of shareholders cannot also be better served, and that, in a word, we have reached the final result—the *ne plus ultra* of railway engineering? It is astounding to find an engineer of Mr. Haughton's ability and position first of all prove that not five per cent. of the load of a passenger train is paying weight, and then proceed to the expression of his belief that his countrymen when "made aware of the actual condition of affairs will accept it as being, on the whole, the best possible," inasmuch as "the railways of the United Kingdom are conducted by an accomplished, scientific, and highly skilled body of experts, who know their business, do it, and don't talk about it, and who, moreover, take out of the locomotive all they can, and present it freely and *exuberantly* to those whom it is their interest as well as their pleasure to accommodate—the travelling community."

It is now about twenty years since an outcry began to be raised unheeded against the extravagant system of our railways. Our present railway system was established in all its vigour in 1845-46. Three years afterwards an engineer of some eminence, Professor Gordon, in a pamphlet on "Railway Economy," put forth this criticism, which was little heeded at the time, but has since become almost common-place:—

"The existing railway machinery will be found monstrously disproportionate to the useful effect produced in four-fifths of the number of times that the machine is put in action. And to this waste of power may be most justly attributed much of the present embarassment of railway companies."

Again in another passage he wrote:—

"These figures indicate the small portion of the mechanism of

the railway system of transport that is actually brought into requisition, even on the most frequented lines. Thousands, nay, millions of miles are run by locomotives and carriages on the present system, while they are performing an amount of transport of passengers preposterously disproportioned to the power and capacity of the trains employed for effecting it."

The protest thus raised has been gradually coming to a head, until at length, in spite of what Mr. Haughton says as to impossibilities, it has been forced upon the public mind that something must and can be done; and we propose to day to direct attention to the solution of the difficulty proposed by the engineer who, in this country, has been foremost in insisting on the necessity of lightening the structure of future railways, and of lightening even while increasing the work of the railways which exist. Mr. Fairlie has long been at work on this question, urging his views in many ways; but he has recently been able to carry out his designs, and to show them in full working order, and the result has been so remarkable that for some weeks past the railway and engineering journals have been constantly engaged in discussion of their merits. Whatever be the result of this discussion, whether to confirm Mr. Fairlie's calculations or to tone them down, or entirely to upset them, the question at issue is so important, and occupies so much attention that it is right to set the leading facts and arguments clearly before the public, leaving them, as far as possible, to form their own conclusions. In so doing, we shall endeavour to avoid technical details and language, and to state the case in plain English for ordinary readers.

First of all, then, let us state that Mr. Fairlie is now exhibiting at the Ironworks at Hatcham a steam-carriage which goes through a surprising performance. The carriage is 43 ft. long, and yet it is driven at the rate of 20 miles an hour on a line of rails laid in a small cabbage garden of about half an acre in extent. It whisks round curves of 50 ft. radius with perfect ease, with scarcely any noise, and without the slightest danger. If the curves had been still sharper—say of 25 ft. radius, the engineer declares that his carriage would curl round them with not less ease, and, if possible, with even greater assurance of safety. The result thus obtained is very striking and full of interest to all who care to study the ques-

tion of railways; but we should state at once that we give it the first place in the record of what Mr. Fairlie has attempted, not because the means by which these sharp curves are rendered practicable are wholly of his invention, but because they lie at the base of whatever subsequent improvements in the construction of rolling-stock he has been able to suggest. An ordinary train cannot pass round sharp curves, because the carriages have a rigid wheel base, of considerable length. Get rid of this rigidity, and we can make the carriages turn. Every one knows how an ordinary four-wheeled carriage is made to turn sharp round on an ordinary road. It is because the front wheels are not rigidly attached to the carriage, but have a horizontal movement underneath it, and independent of it. Now, if we imagine a carriage in which the wheels behind have a horizontal movement similar to that of the front wheels, we shall have a very fair model of what is known in the railway world as a "bogie-carriage," and can understand the principle on which Mr. Fairlie works. "Bogie" is a north-country word for a spirit, a goblin, the devil; and bogie-carriages were first used many years ago in Newcastle, where it was necessary for the coal waggons to double about the quays. They were so named because they were supposed to turn upon one like a spirit, and to face one when least expected. You saw a bogie-carriage going off in a particular direction in full force; in a moment it wheeled round an unexpected curve and was down upon you. "It's Bogie himself," cried the miners; and so the waggon was named. The waggon, instead of being supported on four wheels rigidly combined in the same or parallel planes, was placed on two small but strong trucks, called bogies, which represent the front and hind wheels of the ordinary carriage to which we have referred. Each of these trucks may be supported on one, two, or three pair of wheels, according to the size and strength required, and in the *centre* of each is a pivot—the bogie pin, as it is called—on which the coal-waggon rests. The advantage of the system is that its wheels can encounter a very rapid curve of rails, because they are not locked into the system of a rigid wheel base belonging to the whole waggon. Each of the small trucks under the waggon is independent, and the engineer who has to calculate the curves of his line has in effect to calculate curves for the passage not of

enormous waggons, but of small trucks on which the waggons are poised. The system worked so well at Newcastle that it was adopted in America as best suited to the rude roads of so vast an extent of country, and admirably has it served them, making the traffic easy where, without such carriages, it would be very rough and difficult. And now Mr. Fairlie has adopted this system of poising a carriage upon wheels as the basis of all the improvements which he suggests in the construction of rolling stock, and in particular as the basis of his scheme for light railways. In testimony of its success, he shows, as we have said, a passenger train in working order, careering at 20 miles an hour round a small cabbage garden. It is important to make this demonstration, because if railways are to advance we may be sure that many sharp turns are in store for them. To avoid these sharp turns both in town and country most expensive tunnellings, cuttings, and viaducts have been undertaken, which in the new order of things, fast coming, will no more be tolerated. The rail must be taught to double round a street corner or a steep hill; and in the garden at Hatcham we are shown how this may be done. Most people who have gone to Paris have made a trip to Sceaux, and seen the singularly ingenious contrivance by which the train is made to turn round at the Sceaux station so as almost to take the form of a serpent biting its tail. That is a complicated contrivance unfit for general use. At Hatcham we become acquainted with a simple device which may be used and is used on the roughest roads, and at great velocities.

So far we give Mr. Fairlie no credit for originality, and he claims none, as we understand. He has merely adopted an arrangement which he found ready to his hand, but which he sees more clearly than others to be of immense use in the future of railways, and which he has turned to account with singular ingenuity. Mainly through his urgency it is becoming accepted among our engineers that there is no mode of traction for railways so easy and so convenient as that afforded by the bogie, which has been long adopted in America; and, indeed, without it the American system of railways could never have been established. The long cars used on the American railways, for example, would be impossible without the bogie; and the bogie, as we have already

hinted, has helped to give ease and stability to the motion of trains on rough roads, where, without it, the jolting would have been terrible. It may be worth while to explain this in a few words—for the point is of importance as a contribution to the theory of light and cheap railways, and we shall have to refer to it again and again. A railway carriage or waggon poised directly upon wheels, as usual in this country, is a load supported on two points towards the ends of the different axles in use. Let us for the sake of simplicity fix our attention on a single axle. The superincumbent weight rests at each end of the axle-tree within the wheels; as the carriage is in motion there comes a rough bit of road and a jolt; the carriage is jerked on one side, and its weight comes down on the other with a blow which, despite the carriage-spring through which it passes, must ultimately tell on the rail underneath. The rail has not only to bear the share of load which each wheel conveys to it, but that load is increased with the jolting as by the blow of a hammer. The carriage then rights itself, and in the process jolts back to the other wheel, which in like manner conveys the force of a heavy blow to the rail. So the carriage oscillates with the force of a hammer from side to side until the oscillations gradually die away, and a new series of oscillations with consequent blows succeed at the next bit of rough road. All this hammering adds greatly to the destruction of the permanent way. And how is it avoided or lessened by the use of bogies? It is so, because the load—be it a carriage for passengers or a waggon for goods—is poised on pivots in the centres of two bogies. The load rests on two points which follow a line midway between the rails. There may ensue from this some slight oscillation of the carriage; but it is not an oscillation which hammers alternately on the wheels, and which can disturb to any great extent the centre of gravity. The centre of gravity is maintained in the centre of the line, so that the shock from side to side is reduced to a *minimum*, the comfort of passengers is promoted, and much tear and wear of rails is prevented. The point is well worthy of notice, because, in fact, we here touch upon the chief advantage of the bogie. The most obvious advantage of the bogie is that of quick turning, from which it derives its name. It renders practicable to trains the most rapid curves, and curves of an intricacy which, according to the system

now in vogue among us, it would be madness to attempt. But if its power of adapting itself to curves constitutes its most obvious and showy characteristic, its most important characteristic, and that which most of all recommends it to the engineer who seeks to solve the mighty problem of railways, is the power which it possesses of adjusting and equalizing the load upon wheels, and of steadying the train. It is a matter of no little importance that on the railways of the future we should be able to turn about in a small space, and bogie is, indeed, a good bogie that will help us to such an achievement. But bogie is most of all a good and clever bogie if it will lighten our load and make it easy, like the lubber fiend of the fairy tales that works for us of his own good will. And it is to this power possessed by the bogie of adjusting, equalizing, and easing a load that we are now chiefly to turn our attention in discussing the problem of railways.

Before entering into this discussion, however, and showing how Mr. Fairlie brings the bogie to bear upon it to solve the railway problem, it may be well to complete what has to be said of the bogie, as applied to curves. In travelling round swift curves it is found that both the existing system of coupling carriages and the existing system of buffers are seriously at fault, endangering the stability of the train, and damaging the rails and rolling stock. Everybody knows the accepted system of buffers. These are placed two and two at the extreme ends of the carriages or waggons, right and left. Now, if we place two carriages end to end, upon a sharp curve, it must be evident that, since the carriages represent two rigid straight lines, the buffers on the inner side of the curve will be in close contact, while those on the outer side will be far apart. But if this state of things exists on the level of the buffers, there must be a corresponding condition of things on the level of the wheels. The flanges of the inner wheels will be relieved from the rails, while those of the outer set, which are already from centrifugal force too much inclined in that direction, are pressing hard against them and grinding them to destruction. Another result also follows. In order to permit a state of things by which the buffers on one side of two contiguous carriages shall be pressed together while those on the other side are far apart, the coupling chains of the two carriages must be loose, and from

loose coupling arises the concussion of carriages with which we are all familiar, Passenger carriages on straight lines are generally coupled so as to jam the buffer-heads together. The carriages run much more steadily when so coupled, the oscillations produced from great speed are diminished, and the severe jerks and collisions which we have all felt at the starting or the stopping of a train are prevented. In lines of much curvature it is impossible to have this tight coupling, and hence much knocking, bumping, discomfort, and breakage. Besides which, on goods waggons and cattle trucks it is impossible, in almost any case, to have tight coupling, and hence much damage to goods and much suffering to the cattle; hence, also the necessity of making these waggons stronger and heavier than they need be, in order to resist the force of frequent concussions. Get rid of the buffers altogether and couple the carriages close, says Mr. Fairlie, and you will get rid of these concussions. "It is well known," he says, "that nothing is so beautifully delicate in its movement as an engine passing from rest into motion. Those who may have stood on the footplate and started an engine, even without a train, know that it is done in the most easy and graceful manner. Therefore, by coupling up the train *in one solid mass*, its movement must be as delicate as that of the engine itself, and all the damaging effects of the present system" are obviated. But how is this to be done, at the same time providing for the flexibility of the train? The ends of the carriages and waggons at present meet each other square. Mr. Fairlie proposes, in the first place, that these carriages, where they meet, should present to each other a circular front. This would give them, instead of as at present, in the buffers, two points of contact, the positions of which are invariable, a single point of contact, the position of which would be variable. If the carriages are in a straight line, they will touch in the apex of the curves which they present to each other. If they meet each other at an angle a new point of contact will be formed upon the curve to right or left of that apex. But for this purpose the carriages must be coupled after a new method. According to the present method the coupling chains or bars hold on to the ends of the carriages—from points on the middle of the ends. But this arrangement is obviously impossible if, as Mr. Fairlie proposes, the carriage constructed with curvilinear ends are to meet normally in

the middle of these curves, and are to have free play to move round each other from side to side. It is, therefore, proposed that the junction of carriages shall be effected, not between the ends where they meet, but by a draw-bar passing underneath the carriages from centre to centre. Whichever way the carriages may turn, this draw-bar, being made up of two radii of two circles which are in contact, must always be of equal length.

The advantage, however, of this method of coupling the carriages is not merely that it prevents concussion by screwing up the train in one solid but flexible mass, that carriages and waggons, therefore, saved from the ills of concussion may henceforth be built somewhat lighter, or may be expected to last longer, and that the flange friction of the wheels upon the rails is much diminished, but furthermore the traction of a train upon curves becomes easier and safer. This may readily be explained if we give our attention to a single carriage of the ordinary construction, and imagine it as a straight line. Imagine this straight line—that is, the carriage—placed upon a curve which represents an imaginary line midway between the rails. The straight line will be a tangent to the curve. Its midpoint, which represents the centre of the the carriage, will touch the curve which represents the centre of the road; but its two ends will be off the curve and outside it. There must evidently be a considerable difference if the force of traction exerted upon this carriage seizes the centre, which keeps to the centre of the road, or seizes the end which is off the road, and has an increasing tendency to fly further and further off. If, now, we imagine the carriage represented by a line, not as one of the usual construction, but as one resting on bogies, and if we place these bogies represented by the two ends of the carriage line upon the curve, the line of the carriage will no longer be a tangent, it will be the chord of an arc, and, its midpoint being always within the curve, the force of traction exerted upon it will be directed to pull the carriages inwards, and so to diminish the friction upon the outer rails, and to preserve the centre of gravity always on the safe side.

But in all this the prominent fact to be seized is that the primary object of the engineer is to ease the rail, to steady the train, and in the end to lighten the load. That question of the

management of curves is of subsidiary importance, and, though interesting in itself, it is chiefly interesting as showing the capability of the bogie to solve the problem of easing the rail under the most difficult conditions. Mr. Fairlie, as we have just seen, has struggled with one part of this problem in dealing with the mode of coupling carriages, and their traction. We have now to consider what is most peculiar to his system, and how he proposes to work out such results that, whereas according to Mr. Haughton, every passenger now carried weighs on the average two tons, that is, 40 cwt., and whereas, according to Mr. Samuel and Mr. Fairlie himself, every such passenger weighs 45 cwt., he undertakes that they shall weigh no more than 5 cwt. It has already been sufficiently indicated that he proposes to work this out by means of the bogie. What is peculiar to his use of the bogie is that, having great faith in it generally, he for the first time has ventured to apply it to the driving wheels of the locomotive. Before him the bogie was in use as applied to carriages, cars and waggons, and occasionally to the carrying wheels of the engine; but he has now applied it to all the wheels of the engine, and has certainly got out of it results which are worthy of consideration. The first result, however, is not perhaps that which readers will expect who may bear in mind the earlier paragraphs of this article, in which we laid stress on the need of light railways, and in which we described the light steam carriage in the garden at Hatcham. The first result is the production of locomotives much more powerful than any which have yet been built, and yet much more economical as regards wear and tear of the permanent way and their own wear and tear. Mr. Kirtley, the eminent engineer of the Midland Railway, has taken the initiative in placing one of these double bogie engines to work the heavy coal traffic at the London end of his line. The grand principle of the bogie is that it distributes, economizes, and eases the load. Therefore it not only makes extremely light railways possible, but it makes extremely heavy ones more manageable than they ever were before. Now, as heavy railways are in existence, and the light ones are in great measure still to come, the problem of the former is even more imminent than that of the latter, for Mr. Fairlie's theory is that passenger trains on

all railways should be much lighter than they now are, and that goods trains should be much heavier. And not only is the question of how to deal with heavy traffic more pressing than that which concerns light, but also in examining how the bogie can be turned to account in the solution of the heavy problem, we can see its working more clearly and fully than in the case of light railways. Let us examine the question, therefore, first of all as appertaining to heavy loads on existing railways.

THE RAILWAY PROBLEM.

20th October, 1869.

II.

For heavy goods traffic heavy locomotives are used; but those of the current type have two faults:—They eat up the rails, and their strength is limited.

With regard to the first of these faults it is to be noted that the chief destroyer of the rails is the locomotive. The carriages and waggons are comparatively innocent. It is for the monster engines that year by year engineers are laying down stronger and stronger rails of steel, and still find the greatest difficulty in repairing their ravages. The engineer of the permanent way is in despair for the means of keeping his line in order. Go to him and he will tell you,—"We carry millions of tons of goods on our line, but we might carry as many millions without hurt were it not for So-and-so's engines. They tremble and grind along, and break down all before them. What should remain a perfect road for years with not more than two men to the mile to look after it is now hammered out in as many months, with five times the number of men employed upon it." We have all heard of the great war which is now going on between armour-plate and guns. There is a similar war carried on between the locomotive and the rail. The railway engineer swears against the ponderous locomotive floundering over his road and crushing it to pieces; while the locomotive superintendent swears against the bad roads that wear out the tyres and axleboxes, and breaks the springs of his engines, so that

it is as much as he can do to keep the stock on the road at all. It is to be observed, however, that this process of mutual destruction is not produced by the normal weight of the engine. It is produced by the hammering which comes of imperfect equilibrium. Will our readers be good enough to recall what we attempted to show as to the jumping of an ordinary carriage upon the rails? It is the same with the ordinary locomotive. Poised in a similar manner upon its wheels it rocks from side to side till it bends the rails into a crook like a dog's hind leg, and there are many instances in which the strongest steel rails have to be taken up and replaced in six months. It is calculated that the blows produced by the violent oscillation of a locomotive going at 30 miles an hour may be taken at 60 per cent. added to the weight upon the wheels. If the nominal weight upon the wheel of a locomotive is eight tons, then the momentum of concussion may be taken as raising the weight to more than 12 tons. It is in view of such a tremendous system of destruction, not only for the rails, but also for the machines which roll upon them, that Mr. Fairlie comes forward with his bogie notion. Even before him it was deemed advisable by several engineers who were satisfied of the good effect of the bogie to rest the locomotive upon one; that is to say, one end of the machine was made to rest upon a bogie while the other end was sustained in the usual manner upon axles. By this means the oscillations were diminished, but they could not be entirely removed and the locomotive made quite steady, while at one end the load was so arranged upon axles and wheels that there was a see-saw movement from side to side, coming down upon each pair of wheels with a violent shock. If the oscillation is to be entirely dissipated, there must be a complete surrender to the principle of the bogie. Mr. Fairlie, for the first time, laid the locomotive on a pair of bogies—making even its driving as well as its carrying wheels the wheels of bogies. He has in this way been so successful in getting rid of violent and destructive oscillation that Captain Tyler, the Government Inspector, declares of one of the Fairlie engines on which he travelled at a speed of 50 miles an hour, that it was absolutely free from oscillation, and that its motion was so smooth as to be comparable only to flying.

The other fault, which we imputed to the current type of engine

is that of weakness—of course, comparative weakness. On some of the lines there is an enormous amount of work to be done in the carriage of goods and minerals. The roads are blocked with the trains, so that on the North-Western Railway they have to resort to the costly expedient of tripling the line. The train loads have been gradually increasing, till now it would seem that according to the system in vogue we can go no further. There was a time when the load of 100 tons was considered a great thing; now loads of 300 and 400 tons are an every day occurrence. But the locomotives which are used for these huge loads are, as we have seen, ruinous to the permanent way, and yet they cannot clear off the traffic fast enough. Mr. Fairlie cries aloud to the railway companies:—"Your passenger trains are ten times too heavy, and your goods trains are only half what they ought to be. There is no reason why, by adding several hundred tons to each of them, you should not reduce by one-half the number of your goods trains, which now block the way and create so many accidents." The answer to this is, that, as a matter of fact, we have kept on increasing the loads until at last we have reached the limit of endurance of the rails, and that, as regards the locomotives, we have gone on piling weight upon weight and increasing them in length and breadth and height, until now we have come to a standstill. We cannot increase them in length, because of the rigid wheel-base, which now so much exceeds what it should be that, notwithstanding the very heavy rails employed, it takes more than three times the number of men per mile to repair the line and to keep it in gauge than it used to do a few years ago. We cannot increase them in breadth, as the gauge is the limit to this. And we cannot well increase them in height, as the monsters now look like towers tearing along on wheels, and these wheels, with their vast superincumbent structures, are already overloaded, and in turn overload the rails. But here again strikes in Mr. Fairlie with his answer, which is that by adopting the bogie system of carriage in its entirety we can solve the problem, for we can adjust the weights of the locomotive more equably, we can move it with less disturbance, and we can increase its length without lengthening the wheel-base. Accordingly, he has constructed several locomotives which are not heavier than heavy locomotives usually are, which have

the load so distributed upon the wheels that upon any pair the pressure is not so severe as it is on some of the wheels of locomotives of the current type, and which, nevertheless, possess two boilers, with two pair of cylinders, capable of driving a goods train loaded to 800 tons. One of these locomotives, entitled Progress, is now employed on the Midland Railway, and at a public trial of its powers performed as follows:—There is between Hendon and Kentish Town a rising gradient of 1 in 180 for more than a mile. Up this gradient the locomotive hauled from 60 to 70 loaded coal waggons, weighing 700 tons, at a speed of 15 miles an hour. The engine is only of medium size, according to this principle of construction, and yet it possesses about twice the power of the heaviest in ordinary use.

Mr. Haggard, in his well-known pamphlet, made a remarkable calculation. He stated that if but one penny a mile could be saved on all the miles of train run in the United Kingdom in the course of a year, there would be an additional sum of £618,000 to distribute among the ordinary shareholders. The cost of running a goods train is on the average about 3s. a mile, while its gross earnings are about twice that sum; but suppose that you double the size of the goods train, and therefore earn double, does it follow that you double the expenses? Nothing of the kind. One of the Fairlie engines, capable of performing double the task of an ordinary heavy engine, does not cost nearly double. The original price of the one may be set down at £2,500, that of the other at £3,500. The fuel, oil, tallow, &c., which the one consumes is not nearly double the consumption of the other. It does not require anything like twice the number of men to attend to it. The locomotive laid upon bogies is even less destructive to the permanent way than the ordinary engine; and if the bogie principle could be adapted to the goods trucks, their wear and tear of the rails would also be diminished. Mr. Fairlie, as we understand, claims that the extra expense of the double-loaded goods train would be less than 1s. a mile, but probably this is a sanguine reckoning. Suppose we say 1s. 6d. a mile. Still there is a tempting profit left which is worth grasping at. It is calculated from the last railway returns that the average earnings of a goods train on our best lines are, as we have said, about 10s. a mile, and that its expenses are about

half this sum. If trains could be doubled, the average earnings of each would be 12s. a mile, while the expenses would be increased to less than 4s., as Mr. Fairlie maintains, but to be within the mark we say 4s. 6d. There remains on the transaction a clear gain by the new method of 1s. 6d. a mile for the dividends of shareholders. Besides which, by having one train in place of two, the road is cleared, the risk of accident is diminished, and companies are saved the necessity of constructing at great expense a third line of rails. The system, it is clear, must be especially valuable to railways that possess but a single line.

If now we turn from the consideration of goods traffic and proceed to consider that of passengers, we find a very different state of things, with regard to which opinions vary not a little. On the one hand are Mr. Raphael Brandon, Sir John Bowring, and Dr. Farre crying out for a uniform fare of 1s., which will cover the cost of transit from London to John o' Groats, as well as from London to the Crystal Palace. On the other hand is Mr. Haughton, strenuously insisting on the impossibility of reducing railway fares, and declaring that engineers just now get the very most out of the locomotive, and present it freely and "exuberantly" to the passengers. On the one hand, again, there is Mr. Haggard, in his pamphlet insisting on the necessity of reducing the number of trains in a day; on the other hand, are his critics (ourselves among them) protesting loudly against any such reduction. But at the basis of all that has to be considered there lies the fact, which cannot be too often repeated, that a ton of passengers involves, according to Mr. Haughton's calculations, a train load of 20 tons, and according to Mr. Samuel and Mr. Fairlie, a train load of 33 tons. It is impossible to persuade us, as Mr. Haughton thinks we can be persuaded, to accept such a state of things, "as, under the circumstances, the best that is possible." And we cannot help regarding with some interest Mr. Fairlie's statistics when he assures us that it is quite within the reach of engineering science to carry passengers in such a manner that each one in the train shall count only for five hundredweight of load, and not for the 40 hundredweight which, according to Mr. Haughton, they at present involve. In putting the comparison thus, however, it is open to misconstruction, for by a passenger Mr. Haughton under-

stands an average weight of two hundredweight, counting luggage; while Mr. Fairlie, taking note of the millions and millions of passengers who make excursions without any luggage whatever, insists that a hundredweight and a half, or 12 stone, is a fair average figure at which to rate the passenger. The comparison may perhaps, therefore, be better rendered by saying that whereas Mr. Haughton declares that a ton of passengers weighs in a train no less than 20 tons, and whereas others declare that it weighs no less than 33 tons, Mr. Fairlie asserts that it is quite within the reach of engineering science to make it weigh no more than four tons. And, *prima facie*, it must be admitted that the presumption is all in favour of Mr. Fairlie. If we take an omnibus working on rough ordinary roads, and find that its two tons of passengers weigh no more than four tons in the entire weight of omnibus, horses, and passengers put together, then it is more natural to believe that on easy-going rails, even at an increase of speed, a ton of passengers should weigh four tons than that it should weigh 20. In urging this comparison, however, we have still to beware of error. For it is to be observed that, when in the existing system of railways a ton of passengers is described as weighing in the train-load 20 tons according to one calculation, and 33 according to another, this is an average, into which there enters the fact that many thousands of trains are never loaded to the full, and that indeed very many of them take a load of passengers one way, and then run back empty for another load. On the other hand, when Mr. Fairlie states that according to his system a ton of passengers makes no more than four tons of train load, he assumes that his train carries its full complement of passengers. In the actual working of such a line as he imagines, the passengers must often be much less than the train can accommodate, the result of which is, that when the time comes to strike the average for the entire year, it will be found that the weight of train-load hauled is considerably more than four times the weight of passengers hauled. But no matter. Say the train load were double what Mr. Fairlie imagines, the gain which his system seems to promise ought to touch the hearts of shareholders, and is well worth considering.

How the scheme will work is shown in the small cabbage garden at Hatcham, to which we now return. This garden has been

visited in the last few weeks by thousands of persons, engineers, directors, shareholders, and inquisitive travellers—who are interested in railways, and who have now the opportunity of judging for themselves what can be done. The carriage exhibited may best be described as a steam coach, with compartments, as in an ordinary railway carriage, capable of holding 66 passengers with the usual comfort, and weighing, when fully loaded, about 18½ tons. With regard to the number of passengers which it can accommodate it should be stated that, according to the railway returns for 1867 (the last published) the average number of passengers to a train, taking into account the immense excursion trains all over the kingom, is 73. Therefore this combined engine and carriage, in providing for 66 passengers, makes room for very nearly the average number. Mr. Fairlie has designed another steam carriage on the same plan, which is not exhibited, but which has accommodation for 90 passengers, and, when fully loaded, weighs no more than 20 tons. If still more room is required, nothing would be easier than to add on another carriage. The length of the carriage is 43 feet, including a compartment near the engine for the guard. The carriage at one end rests on a four-wheeled bogie, which it has all to itself. At the other end it rests on another four-wheeled bogie, which, however, it shares with the engine. The bogies upon which it swivels have a wheel-base of less than six feet, and, therefore, despite the great length of the carriage, it can be drawn upon any curves which are fit for a wheel-base of six feet in length to run upon. Actually on this garden the carriage passes round curves of 50 feet radius, and it could easily go round one of 25 feet radius—that is, little more than the diameter of a good-sized turntable. Moreover, although the rails are laid round the garden in a rough and ready fashion, so as to have no pretensions to such smoothness as English travellers are accustomed to, the motion of the carriage—travelling round exceptional curves on a rough-laid road—is easier than that of an ordinary train. Those who doubt can go and see. For the rest we quote from one of the technical journals — *Engineering* —some figures which may be interesting to those who wish to search deeper lnto the action of the new carriage. We confess to some bewilderment at the columns and columns of figures about this carriage which have appeared in every one of the

engineering, mechanical, and railway journals, by all of which, indeed, the new comer seems to be hailed as a Godsend. Those which follow are very simple, and may easily be apprehended by readers of ordinary intelligence. After pointing out that the steam carriage is 18½ tons, the writer goes on to say:

"The adhesive weight is nearly half as much, and the average steam tractive force at least half a ton. The resistance of such a carriage at 25 miles an hour, upon a level, would not exceed 300lb. or 400lb., nor upon a gradient of 1 in 60, more than from 1,050lb. to 1,150lb., the whole actual work done being, say 25-horse power in one case and 75 in the other, or, supposing the speed on the gradient to be diminished to 17 miles an hour, to but 50-horse power. The carriage is not one of the omnibus kind, but has seven compartments and a guard's van, in all respects in conformity with the standard rolling stock of English lines. The weight per wheel being in no case greater than 2½ tons, lines of corresponding lightness would serve as well as heavy lines now serve for heavy engines, loaded as they are from 5, 6, 7, to even 8 tons upon each driving wheel. If even half-filled with passengers, such a carriage at ordinary fares would earn about 5s. per mile, and if filled, of course twice as much. The whole cost of working would certainly be small. When working upon moderately easy gradients the consumption of coal would run but from 6lb. to 8lb. per mile, the wages of driver, stoker, and guard, making 100 miles a day, to but 1¾d. per mile, and repairs to probably less than a pound a day, or 2¼d. per mile, these respective expenses being thus only 5d., or say 6d. per mile, including all train charges. Permanent way, station expenses, and general charges might carry the whole to 1s. or 1s. 3d., but even at twice the last-named cost there would be a high proportion of profit on the work."

We have already observed that a statement which appeared in *The Times*, to the effect that the English is the best served travelling community in the world, has been quoted a little too freely by the apologists of the existing system of management. But, on the other hand, a parallel statement made in these columns, to the effect that the cry of the railway economists for a diminution in the number of trains is a demand to which the public cannot submit, has also been freely quoted as an evidence of the unreasonable

expectations of this travelling community. The advocates of economy show clearly enough that some trains are crowded, that others are but half filled, and that again others are nearly empty; and they also show that it would be a gain to the railways not to run these little-used trains. But we have to look at the question from the point of view of the public, and we honestly think that for their accommodation the trains run are by no means too numerous. If, being so numerous, they are too expensive for the railway companies, we maintain that this is their own fault, and the figures prove it. Say what Mr. Haughton will, we cannot be made to believe this to be the last result of our boasted engineering science—that a ton of passengers must weigh on the average 20 or, it may be, 33 tons. Instead of sending 73 passengers, the average number, in a train weighing 150 tons, why not try to send them, as Mr. Fairlie proposes, in a train which, when fully loaded, is no more than 20 tons? Mr. Fairlie may be over-sanguine in his calculations, but at least he is grappling with the problem of railway economies at its right end, and his claims are worthy of a fair trial. If he can do half of what he undertakes he will deserve our thanks.

A light train does not necessarily imply a light railway. The foregoing remarks, therefore, on the need which exists to lighten our passenger trains and the method of so doing apply equally to heavy and to light railways. But it is not possible to bring this discussion to a close without insisting on the necessity of lightening the construction of future railways. It is lamentable to think of the waste of money in our branch lines through thinly-peopled districts, and in our colonies, where there is great demand for railways, and where the engineers are proposing to build them on a magnificent scale. Our people have now become so accustomed to the railway that all over the country they sigh for its advantages, and there is nothing to stop them from projecting line after line but the enormous expenses which engineers, lawyers, contractors, and directors in combination declare to be essential to their construction. Why, when a little branch railway is to be constructed, engineers, contractors, lawyers, and directors should combine to say that it must be a grand affair is best known to themselves. We only know that this game has now been played out, and that if we are really

to go on building more and more railways in this country it can only be on the condition of their showing in the estimates and in the actual working a set of figures to which our railway kings are little accustomed, and which, perhaps, they might think it scorn to read—figures like those of the little Welsh railway which, built at a cost originally of £2,000 a mile, has yielded to its shareholders a sweet little dividend of 30 per cent. £2,000 a mile for a railway —can anything be more contemptible? Yet perhaps even railway kings may stoop to such meanness for the sake of the dividend returned. In the case of the little Welsh railway to which we have referred—one of 14 miles, between Festiniog and Portmadoc—the returns are 30 per cent. upon its original capital of £36,000, but as in the course of years £50,000 has been taken out of revenue, spent in improvements, and, therefore, treated as so much additional capital laid out, the dividend paid upon this total amount of capital, £86,000, is about 12½ per cent., and the line is still improving.

For one thing in future railways, the cost of land is immensely diminished. Time was when the land had to be purchased at exorbitant prices, and when directors, indeed, had to fight proprietors in Parliament for possession of it. Now, the owners of land are in many cases willing to give it freely for the sake of the advantages returned to them by the railway passing through their estates. And that goes far to diminish henceforth the average of £35,000 a mile which our railways have cost. It will be diminished still further by lightness of construction in the permanent way and by consequent lightness of rolling stock. The lightness and cheapness of the permanent way depend upon several conditions, of which the first and most obvious is that it shall not be constructed as if it had to bear the weight of a colossal traffic when the traffic is as slender as it can well be. On this point it is needless to enlarge. Nor yet on another point on which we have already said enough is it needful to dwell—namely, on freedom from the expense of deep cuttings, tunnellings, and costly viaducts through the necessity of avoiding curvature and keeping the train in as straight a line as possible. Following the bogie method of swinging the carriages, there is no amount of likely curvature in a road which the railroad need shun. It is not merely, however, to avoid curvature that in

railways of the heavy existing type the great expense of deep cuttings, magnificent viaducts, and tunnellings has been incurred. It has also been incurred to avoid steep gradients, since, according to the present system of weighting the wheels of a locomotive, it was impossible to find adhesion enough for the driving wheels. By the use of the bogie and the readjustment and increase of weight which it renders possible, the adhesion of the driving wheels is so increased that Mr. Fairlie and his followers claim for the double-bogie engine the power of doing all the traffic up such a line as the Mont Cenis Railway, ascending the gradients of 1 in 12 with its own natural power of adhesion to the rails, and without the artificial adhesion created by the central rail. We quote such a statement, of course, with all due reserve, and with some doubt whether the engineers who exclaim against the necessity of producing artificial adhesion on a midrail on a gradient of 1 in 12, make sufficient allowance for the influence of climate upon the adhesion of their engines. What are the chances, for example, of slipping in the near proximity to Alpine cold? The statement, however, having been advanced, it may deserve to be quoted for what it is worth; and the more so seeing that, as a matter of fact, there is proof enough that the double-bogie engine does admit of greater adhesion, and therefore of easier ascension upon steep gradients, than the ordinary locomotive.

From these conditions, necessary to the existence of cheap railways —namely, lightness of construction, with great possibilities of curvature and of gradients — we pass on to another which may or may not be of much practical importance—it is difficult to say; but which in connection with the exploits of the double-bogie engine, is not of a little interest—we refer to the question of gauge. Is it essential to cheapness that the gauge of small lines should be diminished? If this question should be answered in the affirmative, it still remains doubtful whether the advantage of saving thus effected is sufficient to counterbalance the inconvenience of isolating this or that branch from the general railway system of the country, established on the universal gauge of 4 ft. 8½ in. But we may state that, since a gauge of 4 ft. 8½ in. has been found sufficient for the heaviest requirements of our heaviest lines, such as the North-Western Railway, it seems very absurd to widen the gauge,

a widened gauge implying heavier rolling stock, for thinly populated districts where the traffic is not to be compared with that of our Midland Counties. In Ireland, the engineers ("exuberantly," as Mr. Haughton would say) widened the gauge to 5 ft. 3 in. In some of our colonies they are still more exuberant, and, for the dear delights of additional expense, lay down a gauge of 5 ft. 6 in. It is a mistake, for in fact great breadth of gauge is one of those causes which must tend to increase the load of a light goods train. Mr. Bidder has stated that "not a single goods train is loaded up to one-fourth of its capacity"—in which phrase we are to understand goods as not including coals and other minerals. And the reason why goods are thus distributed in trains that might contain four times the quantity, will be evident on a little consideration. You can fill a passenger train and empty it quickly, for it empties itself. But goods, which have to be distributed at a number of points in a given line, cannot be thus quickly deposited from the train as it stops at the different stations. The train cannot wait, and it is found easier in practice to allot a whole waggon, or as many waggons as may be required, to the goods intended for a particular station, and to let the train pass on, dropping whole waggons in its transit. But this implies that goods must be distributed in many more waggons than are necessary for the whole lot, and hence the statement of Mr. Bidder that not a single goods train is loaded up to one-fourth of its capacity. Follow this out and see what it means. It means that the goods are put into waggons which are much heavier than is necessary for them. Increase the size of the gauge and you must still more increase the weight of the waggons adapted to it. Diminish the size of the gauge and you can diminish the size of the waggons, diminishing, therefore, the disproportion between the goods to be carried and the capacity of the train to carry them.

What can be done on a railway of extremely narrow gauge is worth noting. The little Welsh railway which we have already spoken of—that from Festiniog to Portmadoc—has a gauge of no more than two feet. It has curves which have been described as being as sharp as the sweep of Oxford Circus; it has gradients of 1 in 80; it has tunnels, one of 60 yards and another of 730 in length; and the inclination of the whole

line with its curves is such that in one direction the trains go down the steep by mere force of gravity. Such is the railway which has paid its proprietors at the rate of £30 per cent. on the original capital, or 12½ per cent. on the total sum invested in it. Now, originally, this railway was worked by horses. Engineers and locomotive builders were afraid of the steam engine as applied to so narrow a gauge, on so steep an incline, varied by such rapid curves. Ten years ago the foremost engineers declared on Parliamentary committees that locomotive power could not safely or usefully be applied to such a line. And when at length the engineer of the line, Mr. Spooner, determined to test this opinion and to try the effect of a locomotive upon it, he could find no locomotive builder but one who would guarantee the satisfactory performance of locomotives upon the line. That one was Mr. George England, of the Hatcham Ironworks. His locomotives began to work on the Festiniog line in 1863. They did so with perfect success and without accident of any kind; but in course of time it came to pass that the requirements of the traffic called for still stronger engines, and then it became necessary to resort to Mr. Fairlie's system of the double bogie. Accordingly, two very powerful locomotives of his construction, one called the Little Giant, the other the Little Wonder, have been placed on the line, and by their extraordinary performance add to the wonders of what is itself the most wonderful railway in the kingdom. These results are notable, not as meaning that railways of two-feet gauge are the sort of railways which it should be our aim to construct, but as showing that even on such a gauge, with all its disadvantages of curvature and gradient—disadvantages which the leading engineers ten years ago declared to be insuperable—the double-bogie engine has been found to triumph. In view of such an achievement, we think we have made out a case for inquiry, and may say that if Bogie is a name of terror in legendary lore it ought to be a name of good cheer in railway annals. All hail to Bogie.

21*st October*, 1869.

We commend the papers we have been publishing on "The Railway Problem" to the attention of all who desire to reconcile the public cry for increased railway accommodation with the shareholders' cry for increased dividends. The public demands reduced

fares. It calls on directors to let millionaires or Sybarites go to Inverness for a shilling first-class, and to let the Stoics who cherish a positive hatred of spring cushions go for sixpence. It wants more trains a day, more branch lines. It will put up with no jolting round curves, no collisions, no stoppages in dark tunnels. On the other hand comes the shareholders with their claim to larger dividends, and murmurs against the number of half-empty trains and insolvent parasite branches. The public craves for more for its money than it gets at present, and the companies retort that it gets even now more than it pays for. The existing state of things being granted to be the only possible state of things, the companies are right in asserting the public to be unreasonable. Investors in railway stock receive rather less than more than the fair return for their investments. There is no margin of profits, out of which additional public accommodation can be carved. But a doubt has for some time been maturing whether the same profits might not be made at a less outlay, and the public take the benefit of the difference. Orthodox railway engineers stoutly affirm the negative. Fares cannot under present circumstances be diminished, because it costs so much to carry the traffic along the road. It costs so much because so much fuel is required to set the engine in motion, because the line is occupied by any given train for so long a time, and because the rails are worn out in so short a time by a given number of trains. Engineering improvements have had no tendency to curtail this rate of expenditure, but rather the reverse. Lines are obliged to carry more traffic, and at a higher average speed; but they do it at a proportionate, or more than proportionate, cost in the wear and tear of material. When a line is required to accommodate an increased amount of traffic the ordinary expedient has been, and is, for the engine-builder to augment the motive power, and thereby the bulk and weight of his locomotives, and for the engineer of the railway to augment the resisting power of his permanent way. The competition has been happily compared to the contest between cannon and armour-plates; but, as in that contest, so in this, whatever steel rails a company can lay down its engine-builder succeeds in battering to pieces.

If this must be so, there is an end to the hope of any substantial reduction of fares—apart, of course, from such as may be made

possible by less ambition and litigiousness on the part of directors. The travelling community ought to "rest and be thankful" that it journeys so cheaply. But certain particulars in the outlay at present needed to provide for railway traffic are so startling that it calls for considerable credulity to believe reform impracticable. In the first place, it is proved on indubitable testimony that, even in goods trains, of the total load dragged along the goods themselves are only 30 per cent., and the remaining 70 per cent. of the weight being dead weight. But in passenger trains, for every passenger that the engine has to draw it has to draw a weight of two tons or two tons and a quarter. That is to say, in passenger trains only 5 per cent. of the load according to the most favourable computation pays. The remaining 95 per cent. travels free, being the wood and iron work of the carriage in which the fare sits. In an omnibus, on the contrary, the non-paying load, the vehicle and horses, weighs only as much as the paying load, the passengers. Under existing conditions, it is, perhaps, necessary that there should be this disproportion on railways between the paying and non-paying loads. With the velocity of steam, carriages weighing no more than their occupants would be impossible things to travel in. But it does not follow that the conditions which necessitate all this dead weight cannot themselves be changed. Any such change must produce an equivalent economy in the conveyance and an opportunity for reducing the fare of the passenger, who now has to frank that huge proportion of dead weight. Every additional ton to be drawn by the engine requires so much additional motive-power and fuel. It requires to have either so many additional engines put in motion, or engines of so much additional bulk and power of consuming fuel. But, in fact, the latter is the only possible remedy for the relief of a line from the goods traffic, which is always accumulating and threatening to block it. More goods trains are of no use where every mile of road is already parcelled out for every five minutes of the day among so many passenger trains. Heavier trains, with more powerful locomotives, are the sole specific to save goods trains from stagnating and congealing in unexpected quarters, and becoming anvils for a mail express to beat out the lives of excursionists upon. More powerful engines, however, as at present constructed, devour more rapidly

rails as well as fuel. The engineer of a railway company's permanent way looks upon them as his natural enemies. He speaks of these Cyclopean monsters as if they took a positive delight in stumbling over his finest steel rails in order the quicker to hammer them out and crush them to pieces. This ruinous waste, too, like that involved in ponderous carriages, is, under existing conditions, a necessity. The force of locomotives has to be enlarged because the exigencies of a line compel the clearing off of as great a weight of goods as possible in a single train. But the more powerful an engine, according to the present principles of construction, the more will it "tremble" or "flounder," and the more, as it rocks from side to side, "bending the rail into a crook like a dog's tail," will it crush and grind it. But, as we said about the proportion of non-paying to paying weight, so we must repeat about this terrible source of loss to a Company from the ferocity of its locomotives. The damages from their oscillation is on some lines enough to necessitate a renewal of the rails every six months. They themselves suffer correspondingly. So long as this wear of material goes on the profit of the traffic is reduced to a *minimum*. But it does not follow that the oscillation which is its condition and apparent cause should not be itself reduced.

Thus, two main conditions of the smallness of railway profits are the excessive disproportion of the part of the load which pays for being carried to the part which is carried without paying, and the wear and tear of rails and engines. Only 5 per cent. of the weight in passenger trains, and 30 per cent. in goods trains pays, and the blows from the oscillation of an engine going at 30 miles an hour are computed to be "60 per cent. added to the weight upon the wheels." Whatever enables the same weight of passengers and goods to be conveyed at a less expenditure of locomotive force economizes in the same proportion fuel, rails, and engines. Mr. Fairlie's "bogie" carriages and locomotives appear to accomplish this end. A carriage under the present system, in consequence of its rigid wheel-base, cannot exceed a certain length, and must be heavy in order to resist concussion. On account of this rigidity in the wheel-base of the several carriages, the train has a difficulty in passing round sharp curves, which must therefore be avoided by means of expensive cuttings, tunnels, or viaducts. Mr. Fairlie

nstead of a carriage supported on one rigid wheel-base, and therefore limited in length and flexibility, constructs a combined carriage and engine 43 feet long in its compartments and cognate arrangements like an ordinary train, but which rests on two four-wheel "bogies," one at either end. These "bogies" are small trucks, each of which, unlike the present railway rigid wheel-base, works independently, like the front wheels of an ordinary four-wheeled carriage. Consequently the engineer was not to consider the exigencies of the carriage above, but only of the trucks beneath. The carriage, measuring nearly the length of an entire train under the present system, has the same power of passing round the sharpest curves which a carriage a fifth part of the length would possess. The same principle applied to the engine, which in Mr. Fairlie's working 43 feet model, shares one of the two "bogies" with the end of the carriage, makes it possible to construct locomotives adapted for the bulkiest goods traffic without increasing the weight. The difficulty of increasing power without increasing the pressure—which is what, falling on a single point, destroys rails—is met by lengthening the locomotive, and this is made possible by means of "bogie" wheels, which distribute the weight equally throughout the whole mass.

Mr. Fairlie claims for his application of this "bogie" principle to ordinary passenger and goods trains that a ton of passengers will by it make no more than four tons of train load, and that there will be an equivalent gain in the goods traffic. He claims also that it will render it possible to carry in one train a far greater weight than at present, and at a far less injury from friction to the rolling stock and the permanent way. He claims, even, that it will open the way to dispensing with the costly engineering processes of providing an absolutely smooth, level, and straight course for trains, since his trains, as supple and flexible as each separate wheel system underneath them, and yet as steady and uniform in motion as one solid mass, will be able to double the most abrupt curves and surmount the steepest gradients. If this be not enough, let us add that by one train being enabled to do the work of two the road is to be cleared, the risk of accident diminished, and the cost as well of compensation for life and limb as of a third line of rails to be saved the Company. If the application accomplish on ordinary railways—and there

seems no reason why it should not—what it is reported to perform in Mr. Fairlie's cabbage-garden, good days are coming for railway shareholders and passengers alike. Even branch lines may become a profitable investment at last. It has been calculated that one penny a mile saved on all the miles of trains run in the United Kingdom in the course of a year would give an additional £618,000 to distribute among the ordinary shareholders. Mr. Fairlie's system, on a computation far more modest than Mr. Fairlie's own, ought to produce a saving of 1s. 6d. a mile. We are afraid to excite unduly shareholders' hopes by reckoning for them what such a saving means.

THE RAILWAYS OF THE FUTURE.

18th February, 1870.

I.

Many persons in England are apt to suppose that we have come to the end of railway extension. The country is so well furnished with railways, and their financial results are so disappointing that people are naturally loth to contemplate any further experiments on the established system. We are most grateful to the shareholders who have been so good as to supply us with these admirable roads, which have gone far to change the character of our civilisation; but there are not many of us who care to follow their example, and we cannot be surprised if they should themselves be unwilling to continue the sacrifice of their fortunes for our benefit. Still, those who are acquainted with the demand for railways in foreign lands, in our colonies, and even in many parts of our own country, must be aware that we are speaking literally when we say that railways are as yet but in their infancy. There is an enormous demand for them in India, for instance; and yet every man of common sense must admit that, judging by all English examples, it is perfect madness to construct them on the received system, which means ruinous expenditure and dead loss. So thoroughly is the need of a great revolution in railway construction perceived, that some months ago we had to make the startling announcement that the Governor-General of India, dissatisfied with the slow progress and

excessive cost of railways in his dominion, had actually sent to the United States for engineers who might confer with him as to the introduction of a more effectual and economical system—as if this were beyond the capacity of English engineers; and we propose now to give some account of further most important investigations tending to the same result as that so earnestly desired by Lord Mayo, whose conclusions, it may be mentioned in passing, coincided substantially with those formed independently by the Duke of Argyle at home.

It may be well to begin by reminding our readers that in October last (the 19th and 20th) we gave a pretty full account of what is known as the Fairlie system of railway working—a system by which lines of the lightest construction and very narrow gauge may accomplish work hitherto deemed within the means only of lines of ponderous construction and broad gauge, and by which also the established lines of standard gauge may either partly diminish expenses, or, without additional cost, well nigh double their carrying capacity. The characteristics of the system will appear in the sequel; for the present we proceed to state that Mr. Power, the vice-chairman of the Poti and Tiflis Railway Company (a railway of 300 versts in the Caucasus) and Mr. Crawley, the contractor for its construction, were so struck with the merits of the Fairlie system, that they strongly recommended its adoption to the Russian Government, not only for the line prepared in the Caucasus, but also for all lines throughout that vast empire, where railways are of prime necessity, and where now, according to the new plan, five miles can be provided at a cost which was swallowed up in three miles according to the old one. The recommendation carried the greater weight, inasmuch as the works of the Poti and Tiflis Railway were far advanced, and on a length of 15 versts the rails are actually laid down. The proposition, therefore, was that the Russian Government would find their advantage, even on these conditions, of changing the plans on which so much work had been expended, taking up the rails which had been laid down, and constructing the line on a gauge of 2 ft. 6 in., or exactly half the standard Russian gauge. The Minister for Public Works, Count Bobrinskoy, seized upon the idea. Mr. Fairlie went to St. Petersburg to explain his scheme in detail; and the result of

all is that an Imperial Commission has been sent over to this country to inspect the actual working of the system in various places, but chiefly on a wonderful little railway of two-foot gauge in Wales.

The chief of the Commission is Count Alexis Bobrinskoy, cousin to the Minister of Public Works. He is accompanied by a considerable staff of engineers, foremost among whom may be mentioned Professor Saloff, of the Russian Imperial Institute; and Mr. Roehrberg, the manager of the most successful railway in Russia; and by personal friends, as Count Zamoyski and Count Alexander Berg, who take an interest in the question of railways. At the same time Mr. Fairlie offered to the Indian Government the opportunity of witnessing the experiments to be instituted for the Russian Commissioners; and they, being themselves anxious for the means of improving and economizing their own railway system, at once resolved to take advantage of the offer. They appointed a Commission, consisting of Lieutenant-General Sir William Baker, R.E., and a member of the Council of India; Mr. Thornton, Secretary of the Public Works Department in the India Office; and Mr. Danvers, Government Director of Indian Railway Companies, to accompany the party. Captain Tyler also, the Government Inspector of Railways, who has already reported favourably on the Festiniog Railway of two-foot gauge, attended on behalf of the Board of Trade, and Mr. Pihl, Chief Engineer of Railways in Norway, was present on the part of the Norwegian Government. Besides these gentlemen, who went to witness the trials officially, others took an interest in the various proceedings in a private capacity; chief among them being the Duke of Sutherland and Count Béla Széchenyi, son of the Hungarian patriot of that name, who was well known in England some thirty years ago. The Duke took an especial interest in the inquiry, as he is not only a director of the North Western Railway Company, but is himself the proprietor of a considerable length of railway on his Sutherlandshire estates.

The party thus constituted started off on Thursday morning last in a special train of saloon carriages, and halting at Crewe to view the magnificent works of the North Western Railway—the largest in Europe, with the exception of those at Creuzot, in France—

proceeded by Shrewsbury into Wales. At Welshpool they entered upon the Cambrian Railway system, and, with the advantage of brilliant weather, were conducted by Mr. Elias through the very picturesque country, up hill and down dale and round curves of hill-sides, by which the line passes to Portmadoc. At Portmadoc is the terminus of the line known as the Festiniog Railway, of two-foot gauge (really one foot 11½ inches), which was the principal subject of investigation.

The Festiniog Railway, which is pronounced by no less an authority than Captain Tyler, the Inspector of Railways, to be the most instructive line in the three kingdoms, and which seems destined by its success to give a new impulse to railway engineering, is itself one of the oldest in existence. The Act for it was obtained in 1832, but in the first instance it was constructed only for horse traction. It is a single line, 13¼ miles in length, with a branch of one mile connecting the slate quarries of Festiniog with the quays of Portmadoc. The terminus of Festiniog has 700 feet of elevation above that at Portmadoc, the average gradient being one in 92, which is enough to secure the descent of the trains on the return journey from Festiniog to Portmadoc by the impetus of gravitation —or, as the Welshman puts it, "by its own impittence." The line runs through a rude, rocky country, and has to adapt itself to an endless variety of curves along the contour of the hills, so that a train of any length has frequently to wriggle in serpentine fashion along two or three reverse curves, some of them sharp enough—the radius being 1¾ chains. On these curves the cant or super-elevation of the outer rails is never more than three inches. The line, in the old days when it was worked by horses, was originally laid with rails of 16 lb. to the yard. When about eight years ago, it was adapted to the locomotive, it was fitted with rails of 30 lb. to the yard, most of which have been in use ever since. These, however, were found too light for the work, and are now being replaced by double-headed rails of 48½ lb. to the yard. The wheels of the carriages being less than 2 feet apart, it is found convenient to arrange most of those for passengers after the fashion of an Irish car, with footboard overhanging the wheels. In this way the carriages are so low hung, and even carriages of the ordinary build are so near the ground in

consequence of the small diameter of the wheels, that the expense of platforms at the stations is avoided. The whole expense of constructing and reconstructing the line, including tunnels, one of them 700 yards in length, with branch lines to the slate company's inclined planes and the quays at Portmadoc—in all, 14 miles—has been £75,000, or at the rate of £5,378 a mile. The value of the rolling stock on the line is £28,000, or at the rate of £2,000 a mile. And now comes the most important point of all, which is that the original capital of the company is £36,185, and that all the extra money which has been laid out upon the line has been taken from revenue. In this sense, therefore, as the net revenue of the company is £10,622, it appears that the line yields a dividend of 29½ per cent. on the original capital. A sum of £50,000, however, paid out of revenue for improvements and reconstructions, has been capitalized—making the total capital £86,185. In this sense the net revenue of the line yields a dividend of 12½ per cent. Whichever way the fact is to be stated, it is a most remarkable one, and must fill many a shareholder's heart with envy.

The chief cause of this wonderful result is the narrowness of the gauge, which has enabled the Festiniog Company to economise in many ways. Thus, for example, the trucks for goods or minerals, even when fully loaded, have less of dead weight on a narrow than on a broad gauge. The best waggons on the standard gauge of 4 ft. 8½ in. are reckoned to weigh about 7 cwt., and to carry 12½ cwt. of pig iron or coal for every foot of their length, the dead weight being in the proportion of 56 to 100 of the *maximum* paying load, or 36 per cent. of the entire load. On the other hand, the waggon for a three-feet gauge is calculated to weigh 2½ cwt., and to carry 8 cwt. for every foot of its length, the dead weight in this case being a very little over the proportion of 31 to 100 of the *maximum* paying load, and under 24 per cent. of the entire load. But there is still another point of view from which it can be shown that the waggons for goods and minerals on a line of narrow gauge are not so disproportionate in weight to the weight carried as they are on the broad gauge. In goods traffic it is well known that the dead weight of a train is enormous—something like 70 or 80 per cent. of the total weight hauled. If goods are to be delivered on a long line of railway, they are in this country arranged in many more

waggons than are necessary to hold them, because a goods waggon cannot, like a passenger carriage, unload itself, and the train cannot wait till the unloading at a particular station is finished. It has to pass on, leaving the waggon of goods for that station behind, and it is more than probable that for this purpose the waggon has been but half or a quarter loaded. This becomes serious when waggons that weigh several tons carry but a fraction, often a small fraction, of their own weight. Such a source of expense disappears to a large extent on a narrow gauge line, where the waggons are comparatively small, and it is but one example of the saving which may be effected in the working of such a line in addition to the saving of cost of construction in the first instance.

This remark would hold good of the narrow gauge in itself and worked according to the ordinary system; but it is in the working of the Fairlie system that the greatest saving of all is effected, and it is mainly, indeed almost entirely, in consideration of the economy, the increased power, and the diminished wear and tear which this system implies that a much narrower gauge than that now in general use has begun to find favour in the eyes of practical men. It was long before the Festiniog Railway Company could get an engineering firm to undertake to build a locomotive for a line of such steep gradients, combined with sharp curves, which they could guarantee. At last Messrs. George England and Co. undertook the task, and supplied engines which worked with perfect success, and then people began to believe in a railway of narrow gauge. One of Mr. Fairlie's engines has now been built for the line—it is called the Little Wonder, as the other engines which have preceded it have been called the Welsh Pony, the Little Giant, as well as by other diminutive names—and the result has so surpassed expectation in the power it exerts, in its gentleness of action, in its economy of fuel, in its saving of the rails, and in its adaptation to troublesome curves and gradients, that for the first time practical men have discovered that a gauge of 2 ft. 6 in., or of 3 ft. at the very utmost, is enough for the heaviest traffic. It is no secret that two engineers of eminence, Mr. Fowler and Mr. Fairlie, have pronounced a 3 ft. gauge to be ample for all the requirements of India, and there were men of position in the party which went down to Wales, men with characters to lose, who made what seems to us

the hazardous statement that on a gauge of even 2 ft. 6 in. they would undertake, with the Fairlie engine to work the heaviest traffic in the world—that of the London and North-Western Railway. Be that as it may, it must be strange for those who can remember the battle of the gauges to find that what was then known as the narrow gauge is now in its turn attacked as being much too broad, and is even described in the terms which have been applied to more than one scheme of the Brunels as a gigantic folly. Our 4 ft 8½ in. gauge is now established in so many countries—it is used not only in Great Britain, but also in France, Belgium, Switzerland, Italy, Austria, Prussia, Denmark, Egypt, the Cape of Good Hope, Australia, the United States, and Central America—that we seem to think of it as a standard of perfection. In some countries there will be found a still broader gauge—as in England itself, in Ireland, in the United States, in Canada, in Australia, in India, in South America, in Portugal, in Spain, in Russia; but in very few will a narrower gauge be found. In England we have 14 miles on a 2 ft. gauge, and a few more on a slightly broader gauge; in Belgium there is a 3 ft. 8 in. gauge; in France, a 3 ft. 4 in. gauge; in India may be found a 4 ft. gauge; and in Norway and Sweden one of 3ft. 6 in.; on the Mont Cenis Railway there is a 3 ft. 7½ in. gauge; and in Queensland one of 3 ft. 6 in.; and now we have opinion tending towards a gauge of 2 ft. 6 in., or of 3 ft., as the standard for the future.

It is easy to determine on light railways of narrow gauge, and to construct them. The difficulty is to work them, and to work them in such a manner that their capacity and their economy shall bear comparison with railways of larger design and more elaborate construction. Hitherto railways of light construction and narrow gauge—that is, narrower than 4 ft. 8½ in.—have been in little favour, because of the limited power and destructive effects of the locomotive. Take, for example, the oscillation. This is very destructive on the standard gauge; it is, indeed, the chief cause of destruction to the permanent way—a fearful item of expense. But it is still worse on a narrow gauge, and necessitates diminished speed on battered rails. Therefore, practically, a narrow gauge was but of limited application to ordinary traffic until a locomotive, such as that of Mr. Fairlie, could be invented free, or nearly free,

from oscillation. And again, since a narrow gauge generally implies lightness of construction, and since lightness of construction implies sometimes roughness of workmanship, and nearly always such an adaptation of the railway to the surface of the country that it must dispense to a great extent with cuttings, viaducts, and other works, and must be ready to accept to the fullest extent possible a line of sharp curves and heavy gradients, it was necessary to devise a locomotive for it capable of good and safe speed on these conditions; and there was none such of sufficient note in existence until the double-bogie engine of Mr. Fairlie was produced, which combined great size and power with freedom from oscillation, and with a short wheel-base that could be worked round curves of 60 ft. radius and even less.

We must reserve for a day or two a full description of the performances of Mr. Fairlie's engines in Wales, because it is desirable to give the results of all the experiments, with their success and their failure together. The last of the experiments is made to day, and we shall state all when we know all; but in the meantime we cannot be wrong in saying that there was an absolute unanimity of opinion among all those who witnessed the working of that narrow gauge railway at Festiniog that the standard gauge of 4 ft. 8½ in. is far beyond all ordinary requirements. There may be some difference of opinion as to the precise gauge which is best. Mr. Spooner, the engineer of the Festiniog Railway, strongly advocated a gauge of 2 ft. 6 in., and he was supported in this view by practical men of great experience; others seemed to hold that a gauge of 3 ft., giving greater freedom of space, would be best, but all appeared to be convinced that a gauge much narrower than that now in general use is capable of work which is at present little imagined in the railway world. If this view be correct, it involves some most important results. Thus, let us take an ordinary line costing £15,000 a mile, and compare it with one of narrow gauge worked in the new system, with power of carrying equal paying loads, and costing, as we have already indicated, three-fifths of the price of the other—namely, £9,000. With a traffic return of £20 every week for every mile, and deducting 50 per cent. for working expenses, the one railway would yield a dividend of about 3½ per cent., while the other would yield very nearly 6 per cent.; and

this calculation makes no allowance for the more economical working of the narrow gauge, which is one of the main features of the system. If such a result be possible, it implies for public lines not a little encouragement to carry the railway system into every nook and corner of the kingdom where a moderate traffic may be obtained; and for Government lines the reduction of tariff to the lowest point.

There seemed to be a unanimity of opinion also as to the success of Mr. Fairlie's engine adapted to the narrow gauge, and also on the broad gauge; but it remains to be seen, from the reports which will be furnished to the various Governments, how far this unanimity extends. That the engine did some extraordinary work is clear, as we shall have to show in a future article; but whether it is or is not to be recommended for adoption as a means of making the narrow gauge available to the utmost is a point on which we have no information.

THE RAILWAYS OF THE FUTURE.

1st March, 1870.

II.

The object of the experiments on the Welsh railways was to ascertain whether or not the Fairlie engine increased the carrying capacity of a railway or diminished the cost of working it. With this view two engines were put on their trial—one, the Little Wonder, on the Festiniog Railway, of 2 ft. gauge, in North Wales; the other, the Progress, on the ordinary gauge of 4·8½, in South Wales.

The Fairlie engine consists of one long boiler, having two sets of tubes, with double fire-box between, and poised on two bogies. The arrangement is such that an enormously increased power is gained, with an extraordinary facility of movement upon swift curves, and with a freedom from oscillation which makes the Fairlie engine less destructive to the rails than locomotives of much less weight and power. The value of the system depends chiefly on the two bogies. It may be necessary to explain for some readers that a bogie is simply the name for a small truck.

Instead of resting a waggon or a locomotive upon wheels of its own, which would make a long wheel-base that could not by any possibility get round very sharp curves, and that might get round moderate curves, but only with an amount of flange-friction destructive to the rails and retarding speed, the waggon or locomotive is poised on two independent trucks, which have a short wheel-base, and which can, therefore, find little difficulty in curves of exceeding sharpness. In the small cabbage-garden at Hatcham, half-an-acre in extent, and laid out with rails of the ordinary gauge, Mr. Fairlie exhibits a steam carriage of 43 ft. in length travelling at a speed of 25 miles an hour round curves of 50 ft. radius; and they could with equal ease, and even greater safety, travel round curves of 25 ft. radius, which is only about that of an ordinary engine turn-table. The engine, therefore, on a pair of bogies, is prepared for a circuitous line of country, even on the standard gauge, which engines of the current type could not attempt.

The excellence of the bogie, however, does not merely consist in its adaptation to curves. It has an extraordinary effect in reducing oscillation. An ordinary carriage rests directly upon the ends of axles, and when, through any defect in the road, there comes a disturbance in the plane of movement the carriage, waggon, or locomotive rocks from side to side with immense violence in a series of oscillations that hammer the rails to their destruction. It is calculated that these oscillations in a train going at the rate of thirty miles an hour, add more than half as much again to the normal weight upon the wheel, and this is very serious in the wheels of a locomotive, each of which may be loaded up to seven or eight tons. The oscillation is reduced to a *minimum* by means of the bogie, inasmuch as the the vast superincumbent weight of the locomotive is balanced on a pin, called the bogie-pin, in its centre. The bogie is a flat table upon wheels, with a great pivot in the middle of it. This table, and the wheels which support it must naturally submit to whatever deflections there may be in the road, and so far it is impossible to get rid entirely of oscillation, but the great mass of weight above being poised in the centre of the bogie and upon the centre of the roadway is comparatively free from the influence of rocking, and transmits little or no hammering to the

rails. A child can understand this by watching at see-saw the difference between placing a weight in the middle of the plank and dividing it between the ends. Now, it is an enormous advantage thus to steady the locomotive, to reduce the tendency to oscillate, and to get rid of the violent impact upon the rails. To steady the locomotive is to make its motion safer and to diminish the chances of its leaving the rails—a point of considerable importance on the narrow gauge. The most important point of all, however, is to save the rails, which are so perishable under the demands of a heavy traffic that there are instances in which the strongest steel rails have to be replaced in six months. The rails where the line has any curve are torn up by the flange-friction of monster engines with an immense wheel-base, and, whether the line is curved or straight, are hammered out by the oscillation of the same engines. We have already explained how in the Fairlie engine the flange-friction is reduced by the substitution of bogies with a short wheel-base for the old plan, which necessitates a long one, and there is an absolute unanimity of opinion as to the disappearance of oscillation with the use of the double bogie.

We have only one word more of preface before we proceed to state what were the experiments with the Fairlie engine, both on the narrow and on the broad gauge. It is that the statements we are about to make do not rest solely on our authority. The various Commissioners and other observers met together under the presidency of the Duke of Sutherland, compared their notes point by point, and came to a perfect agreement as to the facts which they were prepared to vouch for. Our facts, therefore, have the authority of documents signed by the Duke of Sutherland, as chairman of the different meetings which were held; by the Russian Imperial Commissioners; by the Commissioners of our Indian Government; by Captain Tyler, of the Board of Trade, who acted as secretary, and was mainly instrumental in putting the facts into proper form; and by others who were well able to judge.

The Little Wonder is an eight-wheeled double-bogie engine of four cylinders 8 3-16 in. in diameter, with a stroke of 13 in. The diameter of its wheels is 2 ft. 4 in.; its average steam pressure is 150 lb.; its weight is 19½ tons; its total length is 27 ft.; its total wheel-base is 79 ft., and the wheel-base of each bogie, which prac-

tically has alone to be considered is 5 ft. This engine was first of all made to carry from Portmadoc to Festiniog a train made up of 90 slate-waggons, weighing 57½ tons; 7 passenger carriages and vans, weighing 13½ tons, and 57 passengers, weighing 4 tons—in all 75 tons. Add to this its own weight, and we have a total load of 94½ tons. The weight, it will be seen, was considerable, if we take into account the size of the engine, the narrowness of the gauge, the steepness of the gradients, and the sharpness and multitude of the curves. But the chief point of interest in this experiment had reference to the length of the train, which was 854 ft.—nearly the sixth part of a mile. A train of such a length on such a line had to run often upon two or three reverse curves, some of them with a radius as short as 1¾ chains, and it curled and doubled upon itself as it wound among the Welsh hills so that the passengers in the front carriages could, sitting in their seats, make signals to the passengers in the hindmost ones. The engine, being in full gear. took this very long train up the hills and in and out among the curves at an average speed of 14½ miles an hour, and at a *maximum* speed of 26½ miles. Let us here add by way of parenthesis, in order not to refer to it again, that some days afterwards a similar train of 140 empty and seven loaded waggons, weighing in all 101 tons, and measuring in length 1,323 ft.—*that is, a quarter of a mile*—a train so long, in fact, that there were parts of the road on which it had to run on no less than five reverse curves—was by the same engine hauled up the hills at an average speed of 12½ miles, and a *maximum* of 16½. Now, what was the result observed in wriggling along these curves? It was generally observed (we now quote almost *verbatim* from the protocol signed by the chief witnesses) that even on curves of 1¾ chains radius, and at *maximum* speed, there was very little perceptible oscillation or movement on the engine or in the carriages, and by no means such as is felt on comparatively easy curves on ordinary railways. Nor must this remarkable point be forgotten—a fact almost incredible, but yet certified by competent witnesses—*that the oscillation diminished as the speed increased.* The speed, let it be added, is naturally less on a narrow gauge than on a broad one. Captain Tyler, the Government Inspector of Railways, was at first so doubtful of the safety of a high speed on a railway of such narrow gauge and such wild curves as that at Festiniog that

he insisted on limiting the company to a *maximum* speed of 12 miles an hour. Since then, however, his doubts have been so completely dispersed that he has removed all restriction as to the rate of speed; and as a matter of fact the Little Wonder, when necessary, works up to 30 and 35 miles an hour.

Next day the oscillation of the Little Wonder was put to a further test, and compared with that of the other engines—the Welsh Pony and the Mountaineer—which are of the ordinary type. In this series of experiments the speed was confined to 10 or 12 miles an hour on a comparatively level line, the gradient being only 1 in 1,200; and the line was laid with rails weighing only 30 lb. to the yard, and not fished at the joints. On the Welsh Pony and the Mountaineer, tank engines of the ordinary type, weighing, the one ten and the other eight tons, it was found that there was a strong vertical oscillation and a lateral oscillation not so strong. On the Little Wonder, the double-bogie engine weighing 19½ tons, it was found that when riding on the foot-plates there was no oscillation whatever, vertical or lateral, perceptible—only "a smooth floating movement;" and that when riding on the bogie frames there was felt a slight lateral oscillation, though less than on the other engines. It is added that the oscillation of the Fairlie engine, being confined to the bogie, the influence of impact on the rails from the flanges of the wheels was far less than in the case of the Welsh Pony and the Mountaineer, the whole weight of these engines being in the course of their oscillations brought to bear upon the rails.

Next followed some rather tedious but very interesting trials as to the comparative powers of the two classes of engine. The Welsh Pony was selected to represent the common type of engine. It is a four-wheeled locomotive, weighing 10 tons, with cylinders 8⅛ in. diameter, having a stroke of 12 in., and with wheels 2 ft. in diameter. It was in the first instance tacked on to a load of 50 slate waggons full of slate, weighing 123½ tons, To this add 3½ tons for passengers and 10 tons for its own weight, and we get at the entire load of 137 tons. With this the Welsh Pony started from Portmadoc, and, running along the comparative level (1 in 1,200) of the Traeth Mawr Embankment, stopped on a gradient of 1 in 85, unable to proceed further, with

160 lb. to the square inch of steam pressure. Hereupon half the number of waggons was removed, and the load (including passengers and the engine itself) was consequently reduced to 72 tons 17 cwt. With this load it was found that the Welsh Pony could mount the gradient of 1 in 85 easily enough. Being successful with 25 waggons, the question arose could it manage more? It was then tried with 30 waggons, but on the gradient of 1 in 85 it was found that it could not start, though, since the engine-wheels did not revolve, there was no lack of adhesion. Then again the load was reduced to 26 waggons, weighing (with passengers and engine) 73 tons 16 cwt., and it was found that this was the limit of the Welsh Pony's power. It started with such a load on the gradient of 1 in 85, and carried it as far as was necessary at the rate of five miles an hour—the average pressure being 150 lb. to the square inch. If the Welsh Pony could carry nearly 74 tons up such a gradient, and with this load also start on it, what could the Fairlie engine, the Little Wonder, do? It was supposed that it ought to pull double. If the Welsh Pony could, on a gradient of 1 in 85 manage 26 waggons full of slate, weighing with all else 74 tons, surely the Little Wonder could manage 52. Mr. Fairlie said he was quite prepared for this; he would stake the credit of his little engine on its power to carry such a load; and to show that he could be generous, he even added three waggons to the load; he thought his engine could manage 55 waggons. However, as the Welsh Pony had first of all been tried with an excessive load, it was but fair that the Little Wonder should be similarly tried. A train was prepared of 72 loaded waggons of slate, weighing 138 tons 17 cwt., with empty ones weighing 43 tons 10 cwt; and when you add to this 56 passengers, weighing 4 tons, and the weight of the engine itself, 19½ tons, you have a total load of 206 tons. With this load the Little Wonder started from Portmadoc (steam pressure, 165 lb.), and passing along the level embankment, went up the gradient of 1 in 85 with perfect ease, and to the astonishment of all the visitors, who crowded round Mr. Fairlie and shook him heartily by the hand on such a triumph. His engine was warranted to do double the work of ordinary engines, and on trial it was found equal to treble the work. But then arose the question

—The Little Wonder has pulled such a load up the gradient of 1 in 85, having had a good start on the level embankment; can it start with this load on the gradient itself? It was, perhaps, scarcely fair to make the trial, inasmuch as the day was wearing late, and the engine-driver had, through a misapprehension, let the fire run low. Still the trial was made, and with perfect success. There is this further, however, to be added, that whereas the shorter trains were standing when they started, or attempted to start, partly on a curve of 4½ chains radius, partly on a straight line, the train of the Little Wonder being much longer (it was 648 feet), stood partly on the curve of 4½ chains radius and partly on a reverse curve of a little wider sweep, which, of course, means an increased resistance, and might be resolved into an increase of gradient. Also let us add here, to complete the statement, what really happened four or five days afterwards, that whereas these experiments last described were intended to test the extreme power of the engines, other experiments followed to show what the Little Wonder could do, not merely in a short run, but in its ordinary daily work between Portmadoc and Festiniog. It took, for example, a train 407 ft. long, and loaded to 141½ tons, from Portmadoc to Festiniog, at a *maximum* speed of 15 miles an hour and an average one of 11¼. The usual practical load, however, of the Little Wonder upon the average gradient of 1 in 92 is from 90 to 100 tons (exclusive of engine), at from 12 to 15 miles an hour. On a level it is calculated that its power is equal to the carriage of 450 tons, at a speed of 14 miles an hour.

After the experiments on the Festiniog Railway the exploring party met together in council, under the presidency of the Duke of Sutherland, to hear Mr. Spooner read a paper on the wonderful little line of which he is the engineer, and to compare with each other their notes and impressions. Mr. Spooner gave ample information on every detail connected with his railway, which in the year ending June, 1869, had a mineral traffic of 118,132 tons, a goods traffic of 18,600 tons, and a passenger traffic of 97,000 persons, but no night traffic and no Sunday trains. His paper will, no doubt, be published, and those who may be interested in the subject will find in it all the statistics of which we have given

the cream. We only state here that he wound up his remarks by saying that he does not recommend for light railways a gauge so narrow as two feet. The gauge he recommends is one of two feet six inches. The large amount of traffic which can be done with ease on lines of this limit is, he said, really surprising, and with the Fairlie engine it is quite equal to that which can be earned on a 4 ft. 8½ in. gauge. Hereupon the discussion became general, but we can refer to only a few of the opinions which were expressed. The Duke of Sutherland said he wished he had known more of the Festiniog Railway six years ago. "I have expended," said his Grace, "about £200,000 in promoting and making railways in the north. Had these lines been constructed on the narrow gauge, and had they in consequence cost only two-thirds of the sum that has been expended on them, I should have obtained a direct return on this large sum which I have laid out for the benefit of my estates and of the people in those remote districts. As it is, I shall suffer considerable loss." Then Mr. Crawley insisted in a vigorous argument on the perfect sufficiency of the 2 ft. 6 in. gauge, if worked on the Fairlie system, for the heaviest traffic, and on the folly, if this were sufficient, of adding another inch to the guage. The argument may be sound as regards heaviness of traffic, but as other considerations beside the weight to be carried have to be taken into account, as, for example, the comfort of passengers and the bulk of goods, say in a cotton country, it is natural that there should be some difference of opinion as to the precise narrow gauge which is best. It will be seen that Mr. Fowler and Mr. Fairlie have both recommended a 3 ft. gauge for India; and it is not at all unlikely that this gauge may ultimately be adopted in Russia. It is important that on this subject we should give the views of Captain Tyler, whose scientific attainments, and whose large experience as the Government Inspector of Railways, gives a peculiar value to his opinions. He stated in substance at the meeting of commissioners what will be found more elaborated in his printed reports. Thus, in a paper which he read on April 11, 1865, before the Institute of Civil Engineers, he says:—

"It is illegal at present to construct any passenger lines in Great Britain on a narrower gauge than that 4 ft. 8½ in., or in Ireland than

5 ft. 3 in. The Act 9 and 10 Victoria, cap. 87, provides (section 1), 'that after the passing of this Act it shall not be lawful (except as hereinafter excepted [with reference to broad gauge railways]), to construct any railway for the conveyance of passengers on any gauge other than 4 ft. 8½ in. in Great Britain and 5 ft. 3 in. in Ireland;' and (section 6), 'that if any railways used for the conveyance of passengers shall be constructed or altered contrary to the provisions of this Act, the company authorised to construct the railway, or, in the case of any demise or lease of such railway, the company for the time being having the control of the works of such railway, shall forfeit £10 for every mile of such railway which shall be so unlawfully constructed or altered during every day that the same shall continue so unlawfully constructed or altered;' and section 7 gives power to the Commissioners of Woods, &c., or to the Board of Trade to abate or remove such railways, so constructed or altered, contrary to the provisions of the Act. It would, therefore, appear to be necessary, before constructing any railways for passengers on a less gauge than 4 ft. 8½ in., or before attempting to open for passenger traffic any railways so constructed subsequently to the year 1846 (in which the above Act was passed), to endeavour to obtain, if not its repeal, at least a modification of its provisions. That Act was passed after the report of the Gauge Commissioners, when there was a strong feeling against break of gauge, and when there was no immediate prospect of a third and narrower gauge being extensively required. But there is now an increasing demand for branch railways of a minor class. Many coal and mineral lines are in use on a narrower gauge than 4 ft. 8½ in., and others are about to be constructed with ultimate views of passenger traffic. It would, therefore, be an advantage if some smaller gauge were recognized; for, however objectionable the existence of different gauges on important through lines of communication may be, it is quite otherwise with respect to the use of a narrower gauge for feeding branches, in districts where a similar gauge to those main lines would not be commercially practicable. Passengers change carriages under any system at the junctions of less important branches, and it is considerably cheaper to transfer heavy goods from one railway truck to another, than to cart them for several

miles, perhaps over different roads. The Festiniog Railway on which the original gauge has necessarily been maintained, in consequence not only of its own works, but also of those of the tramways and quarry inclines running into it, is an extreme example, outdone only by the little engine which does the work of the shops at Crewe on a gauge of 18 in.; and the cost of that railway, under the peculiar circumstances of its original construction and subsequent alterations, cannot be taken as a guide for the future. A gauge somewhat wider than 2 ft. would probably be desirable on any line to be now constructed, and it would hardly be worth while to desert the gauge of 4 ft. 8½ in. in Great Britain for any gauge wider than 2 ft. 6 in. But whatever the exact gauge, whether 2 ft. 6 in. or 3 ft., or any other dimension that might be considered most suitable for lines of *minimum* traffic, there can be no question that a system of branch lines, costing two-thirds of the branches now ordinarily constructed, and worked and maintained at three-fourths of the expense of those branches, would be of decided benefit to Great Britain and Ireland, and would be most valuable in India and in the colonies; in fact, wherever there are people to travel, produce to be transported, or resources to be developed, where it would not be commercially profitable to incur the expense, in the first instance, of a first-class railway."

On the same occasion he observed:—

"It is important to ascertain what would be a suitable gauge in those instances where the traffic is not likely to be large. Farmers are now using portable railways for transporting the produce of their fields, for bringing in their harvests, spreading manure, &c., and there seems no reason why districts which could not support a railway on the gauge of 4 ft. 8½ in. should be altogether deprived of the advantages of railway communication. The question of gauge is, in one sense, a question of speed. Speaking roughly, on a railway of 2 ft. gauge, with 2 ft. driving wheels, travelling might be made as safe at 20 miles per hour as on the Great Western, with its 7 ft. gauge and 7 ft. driving wheels, at 70 miles per hour. I have travelled on parts of this little line at the rate of 30 miles per hour with every feeling of safety."

And again, in a report on the Festiniog Railway, addressed to the Board of Trade, he says:—

"The adoption of the locomotive power upon this little line is very important, and has evidently been a very successful experiment. The cheapness with which such a line can be constructed, the quantity of work that can be economically performed upon it, and the safety with which the trains run over it, render it an example which will, undoubtedly, be followed sooner or later in this country, in India, and in the colonies, where it is desirable to form cheap lines for small traffic, or as a commencement in developing the resources of a new country."

It should be noted particularly that the inquiries instituted by the Russian and Indian Governments had reference not merely to the narrow gauge, but chiefly to the narrow gauge as made available by the Fairlie engine. Having examined into the working of the Fairlie engine on the narrow gauge they proceeded southwards to see the working of another engine of the same type on the ordinary gauge, on the heavy gradients of the Mid-Wales Railway and of the Brecon and Merthyr line. The Progress was, we believe, the first built of Mr. Fairlie's engines, and has several imperfections, being, for instance, deficient in heating surface. But taking it as the first rough exemplar of the system, its performance is certainly remarkable. It is a double engine, with a four-wheeled bogie under each end, the cylinders 15in. in diameter, the stroke 22 in., and the wheels (4 ft. 6 in. in diameter) are coupled together in both bogie frames, so that all the wheels of the engine are driving wheels. The extreme wheel-base is 22 ft., but, what has alone to be considered in practice, the wheel-base of each bogie is only 5 ft. The heating surface is on the fire-box 92ft., and in the tubes, 1,910ft., making a total of 1,992 ft. The total weight of the engine when fully equipped is 54 tons, including 1¾ tons of coals and 2,000 gallons of water. Also, the engine is fitted with the Chatellier steam break, which Mr. Fairlie was the first to introduce into this country, and its extreme length from buffer to buffer is 32 ft.

On the 14th of February the Progress left the Three Cocks Junction on the Mid-Wales Railway with 39 loaded waggons, three break vans and about 50 passengers and workmen, making a total weight of 526 tons, including the engine. It measured 732 ft. in length. The day was bitterly cold; the hour was late

Mr. Fairlie was anxious to hurry on; and not waiting for the engine driver, who knew the road, he mounted the engine himself, and set off with his load. The result proved that though he may be a first-rate engineer he is not a good engine-driver. A man may be a very good judge of horses and yet not a good jockey. An engine requires as careful management as a horse; and Mr. Fairlie, driving his own engine, made it go through its heaviest work; but when he came towards the end of the journey, and there was a trifle more to be done, it turned out that there was not steam enough to go on. The amateur engine-driver, unacquainted with the gradients, had turned on the water supply at the wrong place, and soon found himself deficient in steam. The same experiment had, therefore, to be repeated next day under the guidance of the regular engine-driver, when it was perfectly successful. The engine had to carry the load of 526 tons up several gradients and on reverse curves; the gradients were 1 in 75, 1 in 162, and 1 in 90. The total distance run was 14 miles, from Three Cocks to Builth, which was done in about an hour, including stoppages. On the same day the engine was taken to some still more severe gradients on the Brecon and Merthyr Railway. She left Tall-y-llyn with a load of 180 tons at 2·51 p.m. After running for three miles for the most part on a descending gradient of 1 in 40, she was brought to a stand at Talybout station, where her tanks were filled. She started from Tallybout at 3·13 p.m., with a steam pressure of 140 lb., and ascended a gradient of 1 in 35 for half a mile. She then mounted a gradient of 1 in 38 for 6⅝ miles, and passed the summit of that gradient at 4.16, with 130 lb. of pressure. She passed through the tunnel—660 long, a rising gradient of 1 in 68—in 2¼ minutes, and was stopped at the Torpantan station at 4·18 p.m., the pressure continuing the same. This portion of the line, as well as the rising gradient of 1 in 38, contained curves of 12, 16, and 20 chains radius, and the train was so long that sometimes it had to pass over reverse curves. These are facts formally authenticated by official witnesses; but further authentic reports have reached London stating that since these trials the Progress has done work still more characteristic of a Hercules. Her performance showed clearly that as the Little Wonder makes a narrow gauge railway of 2 ft. do work hitherto

deemed within the means only of a much broader gauge, so the Fairlie engine, on the standard gauge, enormously increases its working capacity, and that, too, without additional cost in proportion. There is but one opinion of the engineers of the lines examined—Mr. Broughton and Mr. Henshaw—as to the effect of the Fairlie engine upon the rails. It does far more work than any ordinary engine, and yet it is far less destructive to the permanent way.

The invention of the double bogie, by which this result is brought about, is exceedingly simple—so simple that one wonders it was not thought of before. It is like the egg of Columbus—when once it was poised anybody could do the same thing. Now, when we see by the double bogie how to poise an engine so that it shall not oscillate, so that it can be indefinitely increased in size, and so that it shall not murder the rails in its violence, one is inclined to say, "We knew all this before; there is nothing novel here." There is nothing novel, the principle is obvious; but it was never before so applied as to have a practical result, and Mr. Fairlie has the credit of introducing into the construction of the locomotive one of those slight changes which lead right on to a prodigious development and almost to a revolution. We are on the brink of a new era in railways—the narrow gauge era—an era of renewed activity, when every village, almost every farmstead, may have its railway, and if such an era be now at hand it is mainly because the Fairlie engine, by its increased power, by its adaptation to the sharpest curves, by its economy on the rails, and by its freedom from oscillation, even upon rude roads, has rendered it possible. Bogie has arisen to the incantations of Mr. Fairlie, and promises to make the old railways work better than they ever did before, and to make new railways, of lighter, smaller, cheaper construction, that will vie in performance with any of the old.

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